

MMaMS 2012

Analysis of Force Ratios in Conveyor Belt of Classic Belt Conveyor

Gabriel Fedorko^{a*}, Vladimír Ivančo^b^a*Faculty of Mining, Ecology, Process Control and Geotechnology, Technical University of Kosice, Park Komenského 14, 042 00 Kosice, Slovak Republic*^b*Faculty of Mechanical Engineering, Technical University of Kosice, Letná 9, 042 00 Kosice, Slovak Republic*

Abstract

The article deals with analysis of force conditions in a belt of classic belt conveyor by FEA. Analysis determines rolls contact forces acting on the belt at idler station.

© 2012 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of the Branch Office of Slovak Metallurgical Society at Faculty of Metallurgy and Faculty of Mechanical Engineering, Technical University of Košice. Open access under [CC BY-NC-ND license](#).

Keywords: belt conveyor, analysis, conveyor belt

1. Introduction

Knowledge of physical, mainly mechanical, properties of conveyor belt rubbers belongs to important preconditions of trouble-free operation of conveyor belt transportation. Mechanical nature of rubber materials used in belt transportation have among others an immediate effect on the friction between rubber layers of a conveyor belt and a driving drum and/or on the total power consumption. This knowledge is relevant not only in the case of new belts where it helps their optimal selection with respect to the nature and quantity of transported material but also during monitoring the belt changes caused by operation [1]. Harrison [2] dealt with modeling of tension force in conveyor belt which is around driving drum. Hatala et al. [3] dealt with modeling of tension conditions in the sample of conveyor belt and used the finite element method. Mazurkiewicz [4] used the finite element method for analysis of conveyor belt jointing by shackles. Application of technology of computer-aided design to large-scale long belt conveyor is presented in [5]. Nuttall et al. [6] presented a simplified approach to modelling the rolling contact phenomena that occur at the surface of a wheel driven rubber belt. The main aim of this approach is to determine the rolling friction due to hysteresis and the relationship between traction and slip in wheel driven belt conveyors. The resulting model is an expansion of existing linear viscoelastic model consisting of three parameter Maxwell model combined with a Winkler foundation that is used to determine the rolling friction due to hysteresis in a conventional conveyor with a flat belt. Molnar dealt with optimally suspended pipe conveyor in [7]. He also analyzed the design experiences of pipe conveyors from various aspects in [8]. Michalik et. al. [9] deals with using of new Computer Integrated System for the automatized measuring of strength in the conveyor belt of pipe conveyor.

* Corresponding author. Tel.: +421 6023125 ; fax: +4216028023 .
E-mail address: gabriel.fedorko@tuke.sk .

2. Belt conveying

Extractive industry often uses conveyors with troughed form for transport of rocks. The belt is the most expensive part of these conveyors and the conveyor belt is exposed to actions of forces by its transformation to and out of the troughed form [10]. It is very important to optimize the technology of production and using of conveyor belts for economy improvement of belt conveying what is possible for example by optimization of conveyor belt construction, development of construction elements, decrease of production costs, application of high-productive technologies, decrease of costs for maintenance [11]. Therefore the selection of optimal way of its transformation is the key point for extension of operational capability of conveyor belt.

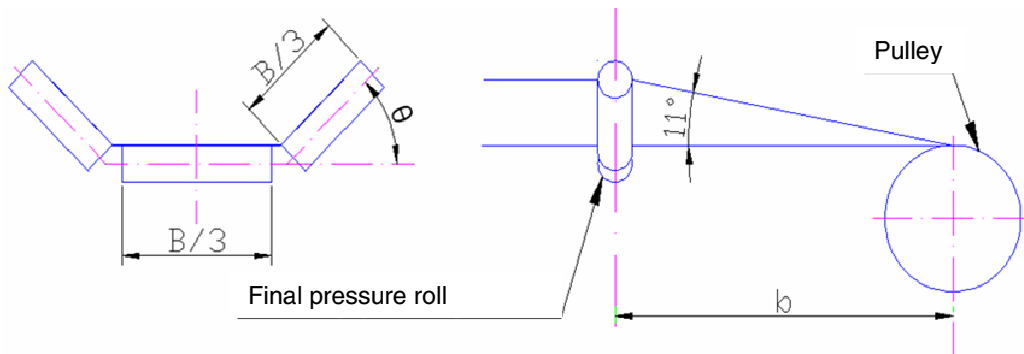


Fig. 1. Principle of calculation of the moulding section of belt conveyor [12].

The principle of calculation of the moulding section is shown in Fig. 1. Length of the transformation proposed by Bridgestone is given by the formula [12].

$$b = \frac{100B}{3} \sqrt{\frac{2(1 - \cos \theta)}{\varepsilon^2 + 200\varepsilon}} \quad (1)$$

where B is conveyor belt width, θ is angle of chute and ε is maximum acceptable deviation (for belt with steel ropes $\varepsilon = 0.2\%$ and for textile belts $\varepsilon = 0.8\%$).

The method of transformation with length b according to formula (1) establishes that belt rests on the pulley with its full width. Anyway, the belt is not in full contact with side rolls at the third idler station. On the base of calculation, the pressure achieves the highest values on the sides of conveyor belt at the third idler station which is the nearest to the pulley of modelled conveyor.

3. Computational model

Geometric model was created by the help of processor implemented in program ABAQUS used for FE analyses. Material properties of rubber-textile belt were defined as elastic lamina with the density $1\,099\text{ kg mm}^{-3}$, Poisson's number 0.499 and shear modulus of elasticity of 2.9 MPa. Young's modulus of elasticity was 5.4 MPa in the cross direction and 397 MPa in the longitudinal direction. The orientation of material properties was defined in local coordinate system of the belt. The material of rolls was considered as elastic and isotropic with properties of steel with the density $7\,850\text{ kg mm}^{-3}$. Young's modulus of elasticity was 204 000 MPa and Poisson's ratio was 0.25.

The problem was solved by non-linear static FEM analysis. The size of the initial time pseudo step was set to 0.1, the minimum allowed time step was $1.0 \cdot 10^{-5}$ and the maximum size of the time increment was defined equal to 1.0. To simplify the computations, the conveyor belt was divided into several parts coming to contact with rolls. For the same reason the rolls are also divided horizontally. As master surfaces (in nomenclature of the program used) were defined surfaces of rolls and pulley. As slave surfaces it were assigned parts of conveyor belt which come into contact to them corresponding surfaces of the roll.

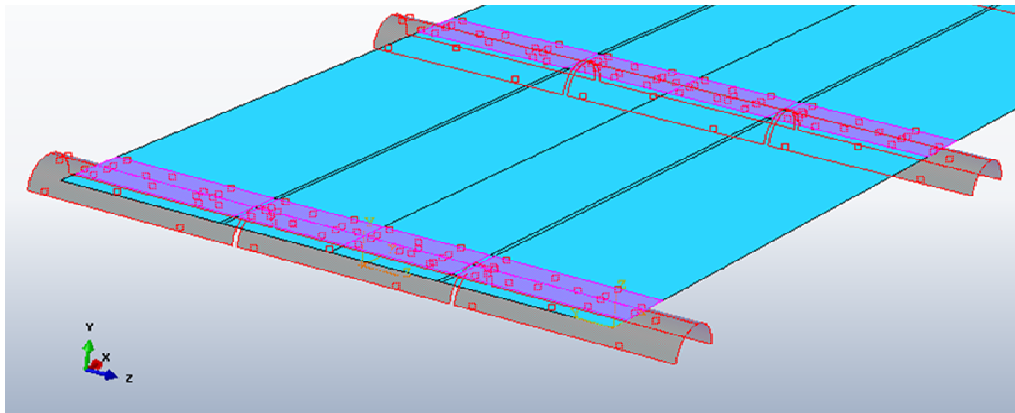


Fig. 2. Areas of contacts among idlers and corresponding part of the belt.

Central rolls as well as the drum have fixed all degrees of freedom. Side rolls were fixed against movement in the x axis and rotation in the y and z axis. These rolls had also an additional boundary condition defining their rotation to the required angle.

No load distributed on belt was considered; only self-weight of the belt represented the conveyor loading. Gravity was defined for the complex model at the direction of the y axis with the value $g = -9\,810\text{ mm s}^{-2}$.

The belt pretension was not considered for reason to accelerate computations. By principle, the program used allows for modeling of tensional preload of the belt. This possibility, which do not need changes of the computational model, will be used in subsequent analyses. Size of elements modelling the rolls was 15 mm and elements modelling the belt had size of 20 mm. Smaller element size can increase accuracy of results but in consideration of hardware possibilities it can cause a considerable increase of computation time.

4. Results of analyses

Results of the calculation illustrate that the highest concentration of the tensional internal forces and by that also the highest stresses of the belt conveyor is at the final idler station that is situated near the driving drum. The highest concentration of stresses is at sides of rolls. Furthermore it can be seen from the results that the stresses are symmetrically distributed.

The results could be analyzed in relation to influence of different belt transformations on overall energy consumption of belt conveyor drive. The presented model has universal validity and after minimal modifications it can be used for analysis of different constructions of belt conveyors.

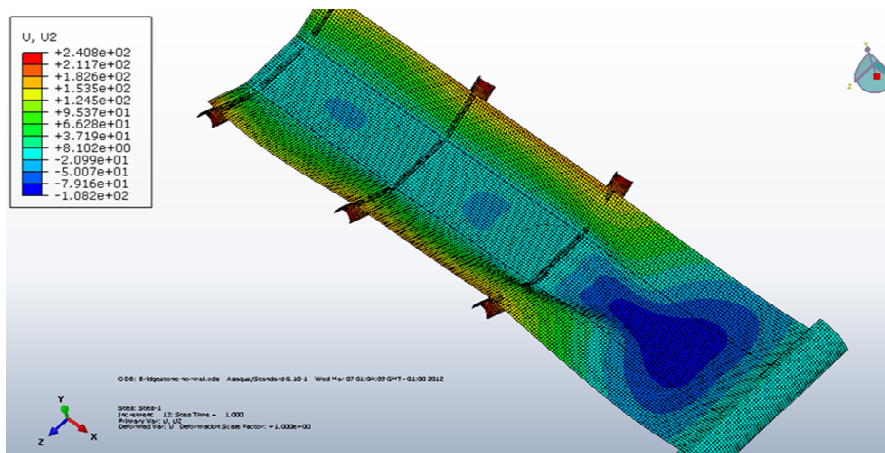


Fig. 3. Deformation of the belt during the transformation

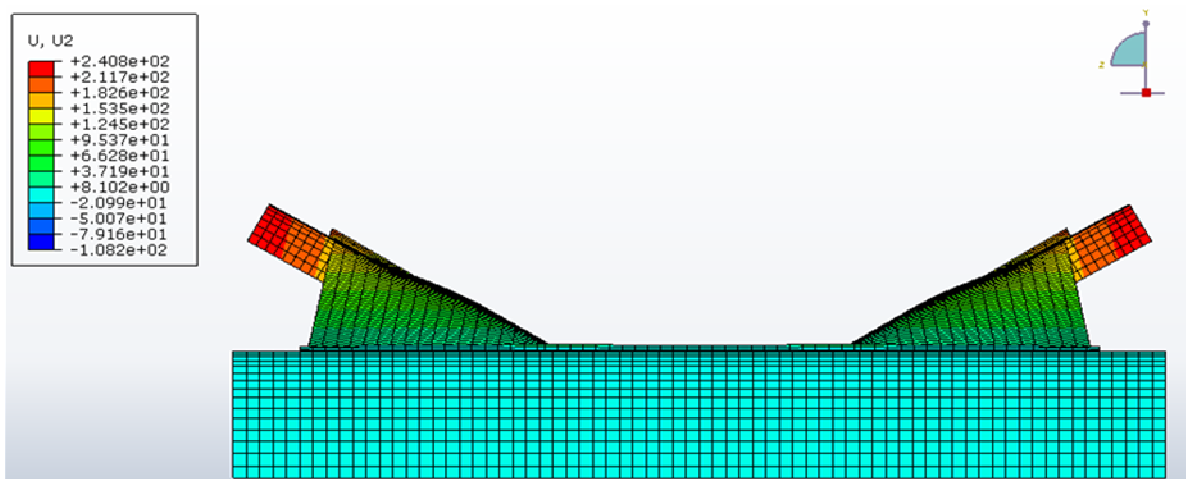


Fig. 4. Deflection of the belt on the drum during the transformation.

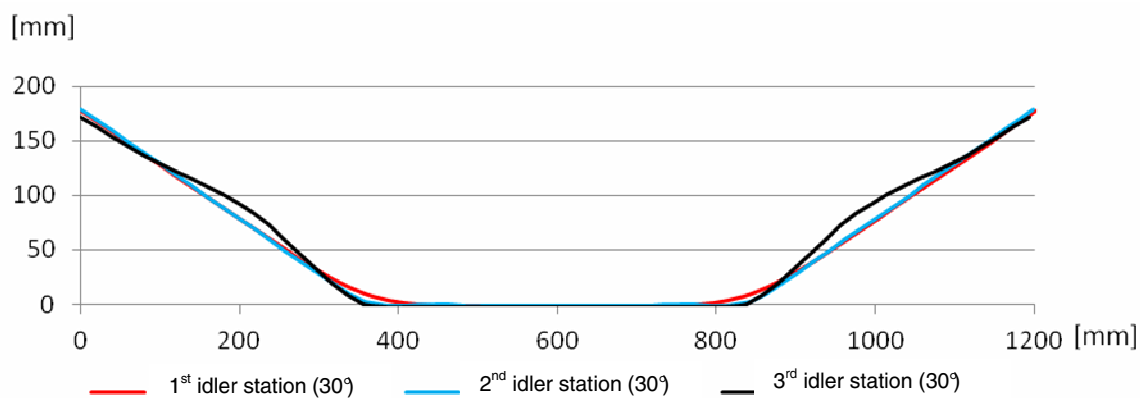


Fig. 5. Deformed shape of the belt at idler stations.

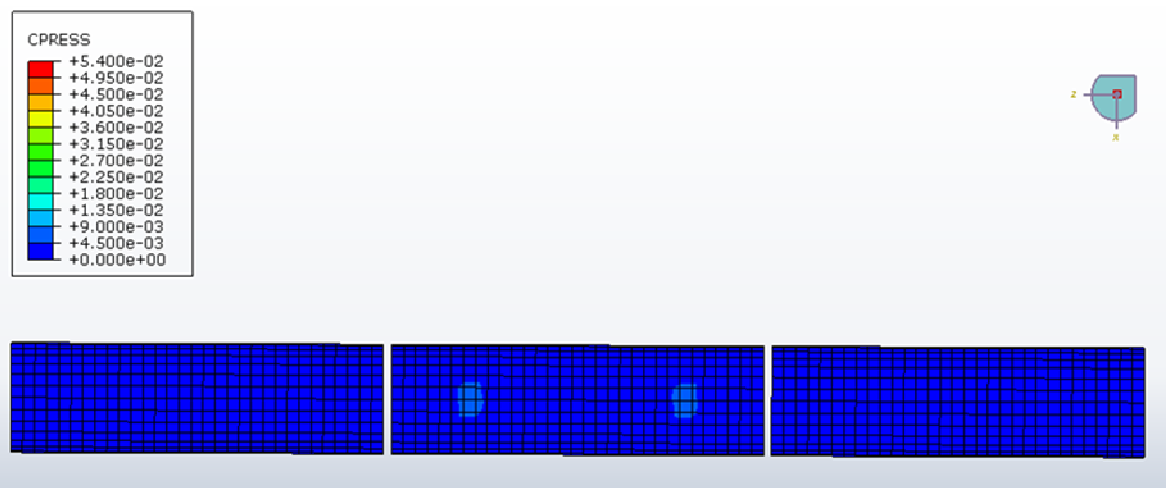


Fig. 6. Contact pressure at the 1st idler station during the transformation.

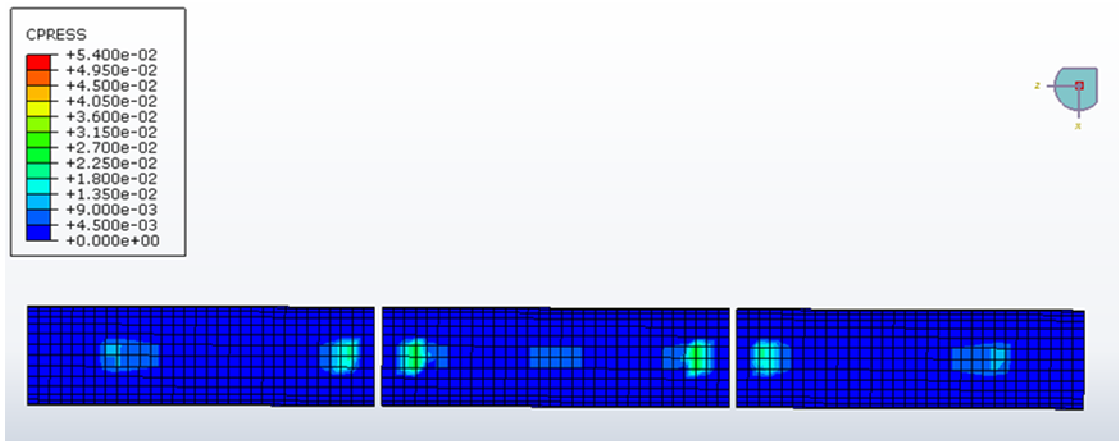


Fig. 7. Contact pressure at the 2nd idler station during the transformation.

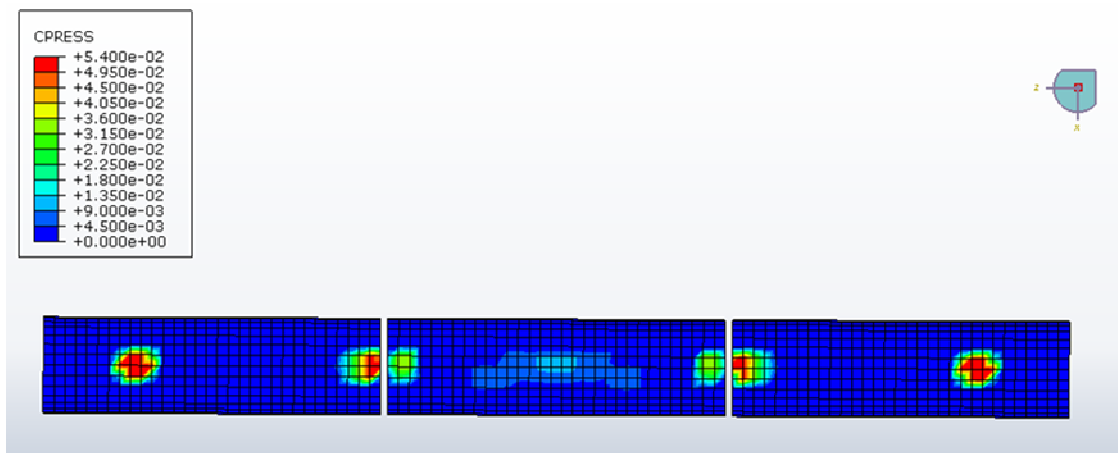


Fig. 8. Contact pressure at the 3rd idler station during the transformation.

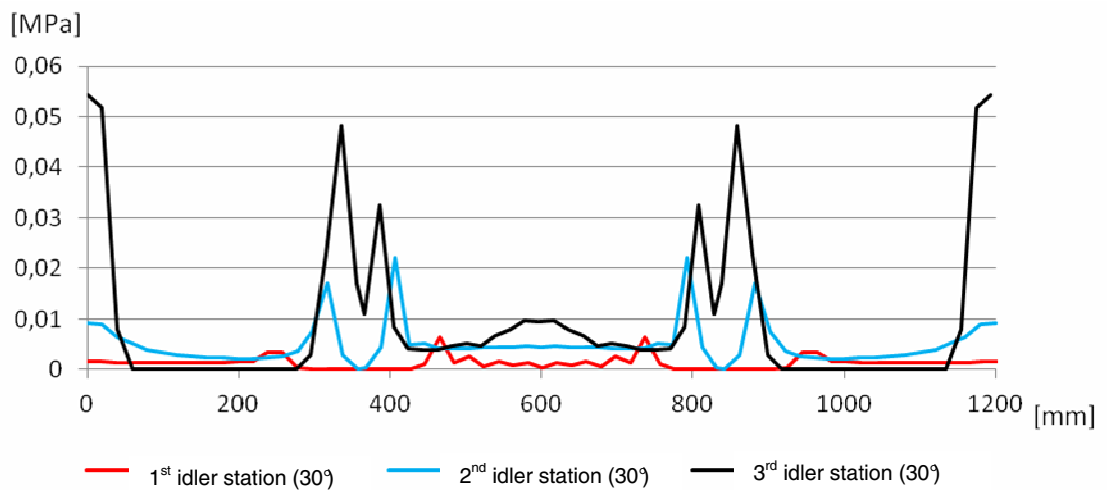


Fig. 9. Distribution of contact pressure in the belt during the transformation.

Acknowledgements

This work was supported by the Scientific Grant Agency of The Ministry of Education of the Slovak republic VEGA by grant number 1/0922/12 and 1/0090/12.

References

- [1] Valentova, H., 2011. "Mechanical and ultrasound properties of conveyor belt rubbers," SGEM2011 Conference Proceedings, 2011, pp. 839-844.
- [2] Harrison, A., 1998. Modelling Belt Tension Around a Drive Drum, *Bulk Solids Handling* 18/1, pp.75-79.
- [3] Hatala, J., Maras, M., 1997. Application of the method finite elements by numerical modeling stress-strain state in conveyor belts. *Acta Montanistica Slovaca* 2, pp. 101-108.
- [4] Mazurkiewicz, D., 2008. Analysis of the ageing impact on the strength of the adhesive sealed joints of conveyor belts. *Journal of Materials Processing Technology* 208, pp. 477-485.
- [5] He, Q., Dong, D. Q., He, Z. R., Ju, J.J., 2010. A New Computer Aided Design System of Belt Conveyor. *Advanced Materials Research* 97–101, pp. 3667-3670.
- [6] Nuttall, A. J. G., Lodewijks, G., Klein Breteler, A. J., 2006. Modelling rolling contact phenomena in a pouch belt conveyor system. *Wear* 260, pp. 1081-1089.
- [7] Molnár, V., 2011. "Optimally Suspended Pipe Conveyor," *Doprava a logistika*, pp. 531-535.
- [8] Molnár, V., Michalik, P., 2011. "Design experiences of pipe conveyors," *Doprava a logistika*, pp. 542-546.
- [9] Michalik, P., Zajac, J., 2012. "Using of Computer Integrated System for static tests of pipe conveyor belts," *Proceedings of the 13th International Carpathian control conference*, pp. 480-485.
- [10] Marasová, D., Husáková, N., Boroška, J., Strakoš, V., Lukáč, S., 2009. *Vnútropodniková doprava v ťažobnom priemysle*. TU Košice, p. 201.
- [11] Taraba, V., Burget, M., Fedora, J., Husáková, N., Kaprálik, Z., Krasňan, J., Malindžák, D., Marasová, D., Martinko, P., Michalko, D., Moško, P., Štvrtecký, V., 2011. *Gumárenské technológie výroby dopravných pásov príručka výroby a použitia dopravných pásov značky Matador*. TU Košice, p. 106.
- [12] Conveyor belt design manual: Bridgestone corporation manual, International Industrial Products Department, Japan.